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(54) METHOD OF DISPLAYING MACHINING TIME OF A SIMULTANEOUS FOUR-AXIS LATHE.

(57) With an NC program for a simultaneous four-axis lathe being prepared, a processor (11) determines machining time T_{1i}, T_{2i} for each of the synchronous steps for each of the tool rests, and determines a total machining time Tm for the simultaneous four-axis lathe by employing a longer machining time for the synchronous steps which effect the simultaneous machining of the tool rests. Then, the total machining time Tm is divided by the number C of characters in the horizontal direction of a CRT (16d) used for bar graph display to calculate the machining time t per character. The machining time of each of the synchronous steps is divided by the machining time t per character to thereby determine the number of characters necessary for displaying each of the machining times. Then, a character pattern for displaying bar graph stored in advance in a character generator (16b) is assigned to each of the machining times by the numbers of characters, and the machining time is displayed in the form of a bar graph on a display screen of the CRT (16d) for each of the tool rests.

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Fig. 4

PROCESSOR 11

ROM 12

RAM 13

WORKING MEMORY 14

KEY BOARD 15

NC DATA OUTPUT UNIT 17

*** NC DATA CREATION *   MACHINING TIME

O1   O2   O3   O4   O5

TOOL REST 1

TOOL REST 2

16

DISPLAY CONT-ROLLER 16a

IMAGE BUFFER 16c

READ CONT-ROLLER 16f

LUMINANCE CONT-ROLLER 16g

CRT 16d

DEFLECTING CIRCUIT 16h

CHARACTER GENERATOR 16b

TIMING SIGNAL GENERATING CIRCUIT 16e

CHARACTER DISPLAY UNIT
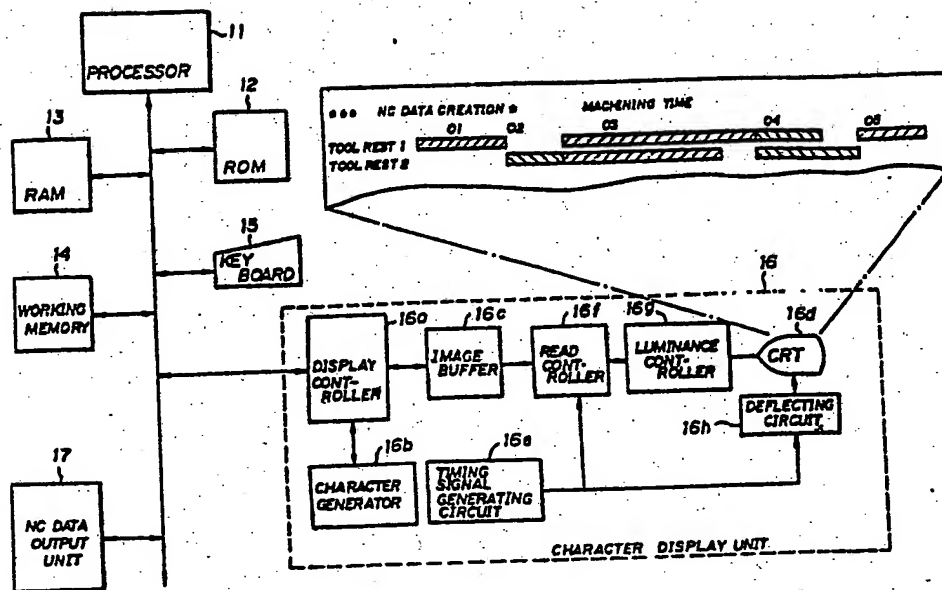
DESCRIPTION

SIMULTANEOUS FOUR-AXIS LATHE MACHINING TIME DISPLAY METHOD

Technical Field

5   This invention relates to a method of displaying the machining time of a simultaneous four-axis lathe and, more particularly, to a simultaneous four-axis lathe machining time display method for displaying, in the form of a bar graph, the machining time of each
10   tool rest of the lathe using a character display unit.

Background Art

An NC four-axis lathe is provided with first and second NC programs corresponding to respective ones of first and second tool rests and having queuing
15   commands. While synchronization is achieved by the queuing commands, movement of the corresponding tool rests is controlled independently by the first and second NC programs to subject a workpiece to machining.

Fig. 1 shows an example of first and second NC
20   programs 1, 2 of this type. The programs respectively include program numbers 1a, 2a, program portions 1b, 2b for executing a first machining operation, first queuing commands 1c, 2c, program portions 1d, 2d for executing a second machining operation, second queuing
25   commands 1e, 2e, program portions 1f, 2f for executing a third machining operation, third queuing commands 1g, 2g, program portions 1h, 2h for executing a fourth machining operation, fourth queuing commands 1i, 2i,

program portions 1j, 2j for executing a fifth machining operation, and tape end commands 1k, 2k.

In accordance with the first and second NC programs 1, 2, the first and second tool rests machine a workpiece simultaneously (simultaneous independent operation) according to the program portions 1b, 2b, and, in response to the first queuing command "M100", the tool rest which finishes the machining operation first waits until the other NC controller reads in the first queuing command "M100".

When the other NC controller reads in "M100", the simultaneous independent operation is performed according to the program portions 1d, 2d. In response to the second queuing command "M200", the tool rest which finishes the machining operation first waits until the other NC controller reads in the second queuing command "M200".

When the other NC controller reads in "M200", the simultaneous independent operation is performed according to the program portions 1f, 2f. Note that since the program portion 1f is blank, the first tool rest immediately assumes a waiting state in response to the third queuing command "M300", and only the second tool rest performs machining according to the program portion 2f.

When machining by the second tool rest ends and the third queuing command "M300" is read in, the simultaneous independent operation starts in accordance

with the program portions 1h, 2h. Thereafter, this four-axis lathe control is performed in a similar manner, with simultaneous four-axis machining being ended in response to the tape end commands M30.

5   Thus, with a four-axis lathe having two tool rests, the tool rests can be controlled and moved independently. Such a lathe is advantageous in that e.g. the outer diameter of a workpiece 13 can be cut by a tool 12 mounted on one tool rest 11 (see Fig. 2) and

10   the inner diameter of the workpiece can be cut by a tool 22 mounted on the other tool rest 21. This enables machining time to be curtailed.

          The NC programs of such a simultaneous four-axis lathe are prepared automatically in conversational

15   fashion by the automatic programming function of an NC unit or by a separately provided automatic programming unit. It is arranged so that the machining times involved in the synchronized processes performed by the tool rests in accordance with the prepared NC programs

20   can be displayed. It should be noted that a "synchronized process" refers to a machining process executed from one queuing command to the next.

          Fig. 3 is an example of a display according to the prior art showing the cutting time and rapid-traverse

25   time of each tool rest in each of the synchronized processes. In Fig. 3, NO. represents a synchronized process number. A process extending from an i-th queuing command to the next queuing command shall be

referred to as an i-th synchronized process.

In Fig. 3, the first synchronized process is drilling performed solely by tool rest 1. The cutting time displayed for this process is 30 seconds, and that

5   for the rapid-traverse time is 9 seconds.

The second synchronized process is outer diameter roughing performed solely by the tool rest 2, for which the cutting time displayed is 18 seconds and the rapid-traverse time 7 seconds.

10   The third synchronized process involves inner diameter roughing and outer diameter roughing performed simultaneously by the first and second tool rests 1, 2, respectively. The cutting time and rapid-traverse time displayed for inner diameter roughing are 1 minute 10

15   seconds and 18 seconds, respectively, and the cutting time and rapid-traverse time displayed for outer diameter roughing are 55 seconds and 18 seconds, respectively. The machining times for the other synchronized processes performed by the tool rests are

20   displayed in a similar manner.

Displayed lastly are the total cutting time and total rapid-traverse time using the longer of the cutting and rapid-traverse times of the processes performed simultaneously by the tool rests 1 and 2.

25   With this conventional method of displaying machining times, however, the machining time of each synchronized machining process performed by each lathe is displayed in the form of characters. For this

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reason, the displayed times are difficult to read and it is difficult to ascertain where time is being wasted and to what extent machining is being performed simultaneously.

5   Accordingly, an object of the present invention is to provide a simultaneous four-axis lathe machining time display method which displays time in an easily readable manner and which makes it possible to readily ascertain where time is being wasted and to what extent
10 machining is being performed simultaneously.

Another object of the present invention is to provide a simultaneous four-axis lathe machining time display method for displaying the machining time of each tool rest in the form of a bar graph.

15   A further object of the present invention is to provide a machining time display method through which the machining time of each tool rest can be displayed as a bar graph on a character display unit not having a graphic function.

20 Disclosure of the Invention

When the NC programs of a simultaneous four-axis lathe have been conversationally prepared, the machining times of synchronized processes are obtained for each tool rest and total machining time for
25 machining performed by the simultaneous four-axis lathe is obtained by using the longer of the machining times for the synchronized processes in which machining is carried out simultaneously by the tool rests. Next,

the total machining time is divided by the number of characters in the horizontal direction (e.g. the number of characters on one line) of the display screen used when displaying the machining times of the tool rests as bar graphs, thereby calculating machining time per character. Thereafter, the machining time of each synchronized process is divided by the obtained machining time per character, thereby determining the number of characters N_i necessary for displaying the machining time of each process.

When the number of characters has been obtained, N_i-number of character patterns for bar graph display are used to display, in the form of bar graphs, the machining times for each tool rest.

Brief Description of the Drawings

Fig. 1 is an example of first and second NC programs in an NC four-axis lathe;

Fig. 2 is a view for describing an NC four-axis lathe;

Fig. 3 shows an example of a conventional machining time display;

Fig. 4 is a block diagram of an automatic programming apparatus for practicing the method of the present invention;

Fig. 5 shows an example of a character pattern for a bar graph display;

Fig. 6 is a flowchart of processing in accordance with the invention;

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Fig. 7 is a chart illustrating machining times and character numbers, which are stored in a working memory, for each tool rest in each synchronized process; and

Fig. 8 shows an example of a display of machining times in accordance with the invention.

Best Mode for Carrying Out the Invention

Fig. 4 is a block diagram of an automatic programming apparatus for practicing the method of the present invention.

Numeral 11 denotes a processor, 12 a ROM, 13 a RAM, 14 a working memory, 15 a keyboard, 16 a character display unit, and 17 an NC data output unit.

The character display unit 16 has a display controller 16a, a character generator 16b for storing various character patterns inclusive of bar graph display character patterns and for outputting a predetermined pattern, an image buffer 16c for storing one frame of a character image, a CRT 16d, a timing signal generator 16e for generating a horizontal synchronizing signal and a vertical synchronizing signal, a read controller 16f for reading and outputting character images from the image buffer 16 in synchronism with beam scanning of the CRT 16d by means of raster scanning, a luminance modulating controller for carrying out luminance modulation control based on a picture signal outputted by the read controller 16f, and a deflecting circuit 16h for deflecting the beam

horizontally and vertically in synchronism with the timing signal outputted by the timing signal generator. The image buffer 16c has a single storage area corresponding to one pixel of the image displayed on the CRT display screen. The arrangement is such that an image is read out of the image buffer pixel by pixel by means of the read controller.

The character generator 16b is constituted by a ROM and stores an (n x m)-bit character pattern corresponding to each character code. As shown in Figs. 5(A) through (C), the character generator 16b also stores, in correspondence with a predetermined code, a paint pattern [Fig. 5(A)] or hatched pattern [Figs. 5(B), (C)] for a bar graph display.

Fig. 6 is a flowchart of processing illustrating the machining timing display method of the present invention. The method of the invention will now be described with reference to this flowchart.

When data necessary for creating NC programs are inputted conversationally using the keyboard 15 and display unit 16, the processor 11 uses these data to create the NC programs and display tool paths on the CRT 16d.

The processor 11 executes the following processing concurrently while the tool paths are being displayed:

(1) First, the operation $1 \longrightarrow i$ is performed.

(2) Next, machining times T_{1i}, T_{2i} of first and second tool rests for an i-th synchronized process are

determined.

It should be noted that "machining time" referred to here is the sum of cutting time and rapid-traverse time. Accordingly, cutting time is obtained from cutting velocity and cutting distance, rapid-traverse time is obtained from rapid-traverse velocity and traveling distance covered during rapid-traverse, and machining time is determined by taking the sum of these two times. Each machining time is stored in the working memory 14.

(3) When the machining times T_{1i}, T_{2i} have been obtained, it is checked whether the machining times for all of the synchronized processes have been calculated.

(4) If the machining times for all of the synchronized processes have not been calculated, then the operation $i + 1 \longrightarrow i$ is performed and processing is repeated from step (2) onward. If these machining times have been calculated, then the processing set forth below is executed. It should be noted that by virtue of the foregoing, the names of the processes as well as the machining times, cutting times and rapid-traverse times of the first and second tool rests are stored in the working memory 14 to correspond with the synchronized process numbers, as shown in Fig. 7 (cutting times are shown in the parentheses on the left side, and rapid-traverse times are shown in the parentheses on the right side).

(5) When the machining times T_{1i}, T_{2i} of each

synchronized process have been determined, these are

used to calculate the total machining time T_m.

The total machining time T_m is found by using the

machining times of the individual tool rests for those

5   synchronized processes performed solely by one tool

rest or the other, and, for those synchronized

processes performed by both tool rests simultaneously,

using the longer of these machining times.

(6) If a request to display machining times is

10   received from the keyboard 15 under these conditions,

the processor 11 calculates time (rough machining time)

per character in accordance with the equation

$$T_m/C \longrightarrow t \qquad \qquad (a)$$

where C represents the number of characters (e.g. the

number of characters on one line) of the CRT 16d used

15   when displaying machining time in the form of a bar

graph.

(7) When the rough machining time t has been

found, whether or not machining processes whose times

are less than the rough machining time t exist is

20   checked with regard to the machining time T_i that

participated in the calculation of the total machining

time T_m.

(8) If such a machining process does exist, the

number P of the processes whose machining times are

25   less than the rough machining time and the total

machining time T_p of these processes are calculated.

(9) Next, a new time (rough machining time) t per

character is calculated in accordance with the equation

$$(T_m - T_p)/(C - P) \longrightarrow t \qquad (b)$$

(10) After the new rough machining time t is calculated, or when it is found at step (7) that a synchronized process whose machining time is less than that of the rough machining time does not exist, the arithmetic operation indicated by the equation

$$T_i/t \longrightarrow C_{ji} \qquad (c)$$

is executed and the remainder is also stored in memory.

In the above equation, T_i represents the machining time of the i-th synchronized process that participated in the calculation of the total machining time T_m, and the quotient is the number of characters necessary for displaying, in the form of a bar graph, the machining time T_i of the i-th synchronized process. If the quotient is zero, the number of characters is regarded as being one, and the remainder is made zero.

(11) When the numbers of characters for all of the synchronized processes have been obtained through step (10), the total value thereof is subtracted from the number of characters C and the remaining characters are assigned one by one starting from the largest of the remainders stored in step (10).

(12) Thereafter, Eq. (c) is used to obtain the number of characters for displaying the machining times of the synchronized processes that did not participate in the calculation of the total machining time T_m. If a quotient is zero, the number of characters is made

one.

As a result of the foregoing, the number of characters for each tool rest is obtained in correspondence with each synchronized process number, as shown in Fig. 7. The examples of the numerical values shown in Fig. 7 are for a case C = 80.

(13) When the numbers of characters have been found, the processor 11 allots the patterns for bar graph display stored in the character generator 16b to the numbers of characters and their respective machining times, generates character code data which will cause the machining times of each tool rest to be displayed as bar graphs and cause the machining times to be displayed as characters on the CRT display, and sends these data to the display controller 16a.

The display controller 16a causes the character generator 16b to successively generate character patterns conforming to the character code data received from the processor 11, and stores these character patterns in the image buffer 16c. Thus, one frame of a machining time display image is stored in the image buffer 16c.

Thereafter, the machining time display image is read out by the read controller 16f in synchronism with the raster scanning of the beam and is displayed on the CRT 16d.

Fig. 8 is an example of a machining time display according to the present invention. The machining time

for each synchronized process performed by the
respective tool rest is displayed as a bar graph, and
the machining times are also displayed in the form of
characters as in the prior art.

5   When the bar graphs indicating the machining times
of an i-th synchronized process and the next
synchronized process are continuous, the patterns of
the continuous bar graphs are made different from each
other or, if the CRT is a color CRT, they are displayed
10 in different colors.

   Thus, in accordance with the present invention,
the arrangement is such that the machining times of the
synchronized processes performed by the tool rests of a
simultaneous four-axis lathe are displayed over the
15 full screen as bar graphs and not just in the form of
characters. This provides an easily readable display
and makes it possible to ascertain where time is being
wasted and to what extent machining processes are being
performed simultaneously.

20   Further, in accordance with the invention, a
character generator is used to display the bar graphs.
It is therefore possible to display machining times in
a simple manner even when the machining time display
based on characters and the machining time display
25 based on bar graphs are mixed.

CLAIMS:

1.   In a machining time display method for displaying,
in the form of bar graphs, the machining times of each
tool rest for every synchronized process in a
simultaneous four-axis lathe in which there are
provided first and second NC programs corresponding to
first and second tool rests and having queuing
commands, wherein a workpiece is machined by
controlling movement of the corresponding tool rests
independently in accordance with the first and second
NC programs while synchronization is achieved by said
queuing commands, a simultaneous four-axis lathe
machining time display method characterized by
comprising:

a first step of obtaining a total machining time
T_m of machining performed by the simultaneous four-axis
lathe by determining and storing machining times T_{1i},
T_{2i} of each synchronized process for each tool rest and
using the longer of the machining times of those
synchronized processes that are carried out
simultaneously by the tool rests;

a second step of calculating machining time per
character by dividing said total machining time T_m by a
number of characters C used for bar graph display;

a third step of determining a number of characters
necessary for displaying the machining time of each
synchronized process by dividing the machining times of
the synchronized processes by the obtained machining

time per character; and

a fourth step of displaying the machining time for each tool rest in the form of a bar graph by allotting patterns for bar graph display stored beforehand in a character generator to said calculated numbers of characters and respective machining times.

2. A simultaneous four-axis lathe machining time display method according to claim 1, characterized in that said second step includes the steps of:

determining a rough machining time per character by dividing the total machining time T_m by the number of characters C;

checking whether processes whose machining times are less than the rough machining time exist with regard to machining times that participated in calculation of the total machining time T_m, and calculating a number of processes P whose machining times are less than the rough machining time and a total machining time T_p of these processes; and

calculating a true machining time t per character in accordance with the following equation:

$$(T_m - T_p)/(C - P) \longrightarrow t$$

3. A simultaneous four-axis lathe machining time display method according to claim 2, characterized in that said third step includes the steps of:

obtaining a quotient and a remainder by dividing a machining time T_i of each synchronized process that participated in calculation of the total machining time

T_m by the machining time t per character;

adopting the quotient as the number of characters necessary for displaying the machining time T_i in the form of a bar graph, and allotting one character to a
5 process for which the quotient is zero;

obtaining a difference between a total value C' of the numbers of characters in all of the synchronized processes and the number of characters C;

assigning, one by one, a number of characters
10 equivalent to the difference to synchronized processes for which said remainders are large; and

obtaining a number of characters necessary for said machining time display by dividing the machining time of each synchronized process that did not
15 participate in calculation of the total machining time T_m by the machining time t per character.

4.   A simultaneous four-axis lathe machining time display method according to claim 1, characterized in that if bar graphs of contiguous synchronized processes
20 are continuous, patterns for bar graph display which differ from each other are used in such a manner that a boundary between the bar graphs is rendered distinguishable.

25

Fig. 1

1   2

| 01223 : | 1a | 2a | 02543 : |

G50 X ____ Z ____ :
G00 X ____ Z ____ :
S100 M03 :

1b   2b

M100 : 1c   2c   M100 :

S150 :
G00 X ____ Z ____ :

1d   2d

M200 : 1e   2e   M200 :

S100 :
G00 X ____ Z ____ :

1f   2f

M300 : 1g   2g   M300 :

S120 :
G00 X ____ Z ____ :

1h   2h

M400 : 1i   2i   M400 :

S200 :
G00 X ____ Z ____ :

1j   2j

M30 : 1k   2k   M30 :

Fig. 2

Fig. 5

(A)   (B)   (C)

Fig.3

☆☆☆ NC DATA CREATION ☆☆☆   MACHINING TIME

NO.		(TOOL REST 1)		(TOOL REST 2)	
		CUTTING	RAPID-TRAVERSE	CUTTING	RAPID-TRAVERSE
01	DRILLING	0'30	0'09		
02	OUTER DIAMETER ROUGHING			0'18	0'07
03	OUTER DIAMETER ROUGHING			0'55	0'18
	INNER DIAMETER ROUGHING	1'10	0'18		
05	OUTER DIAMETER FINISHING			0'32	0'16
	INNER DIAMETER FINISHING	0'21	0'10		
07	THREAD CUTTING	0'25	0'07		
	TOTAL TIME	2'55	0'57		

Fig. 4

*** NC DATA CREATION *

| | O1 | O2 | O3 | O4 | O5 |
| | MACHINING TIME | | | | |

TOOL REST 1

TOOL REST 2

CHARACTER DISPLAY UNIT

CRT — 16d

DEFLECTING CIRCUIT — 16h

16 —

LUMINANCE CONT-ROLLER — 16g

READ CONT-ROLLER — 16f

IMAGE BUFFER — 16c

TIMING SIGNAL GENERATING CIRCUIT — 16e

DISPLAY CONT-ROLLER — 16a

CHARACTER GENERATOR — 16b

PROCESSOR — 11

ROM — 12

KEY BOARD — 15

RAM — 13

WORKING MEMORY — 14

NC DATA OUTPUT UNIT — 17

Fig. 6

START

(1) $1 \rightarrow i$

(4) $i + 1 \rightarrow i$

(2) OBTAIN MACHINING TIMES T_{1i}, T_{2i} OF FIRST AND SECOND TOOL RESTS IN i-th SYNCHRONIZED PROCESS

(3) ALL MACHINING TIMES OBTAINED ? NO

YES

(5) CALCULATE TOTAL MACHINING TIME Tm

(6) OBTAIN TIME (ROUGH MACHINING TIME) t PER CHARACTER ($Tm/C \rightarrow t$).

(7) DO MACHINING PROCESSES WHOSE MACHINING TIMES ARE LESS THAN ROUGH MACHINING TIME T EXIST AMONG MACHINING PROCESS TIMES THAT PARTICIPATED IN Tm ? NO

YES

(8) OBTAIN NUMBER OF MACHINING PROCESSES P WHOSE MACHINING TIMES ARE LESS THAN ROUGH MACHINING TIME, AND OBTAIN TOTAL MACHINING TIME Tp THEREOF

(9) $(Tm - Tp) / (C - P) \rightarrow t$

(10) OBTAIN NUMBER OF CHARACTERS OF MACHINING TIME OF EACH MACHINING PROCESS

(11) ASSIGN REMAINING CHARACTERS

(12) OBTAIN NUMBER OF CHARACTERS NECESSARY FOR DISPLAYING MACHINING PROCESS TIMES THAT DID NOT PARTICIPATE IN Tm

(13) GENERATE AND DISPLAY PICTURE DATE FOR MACHINING TIME DISPLAY

END

Fig.7

SYNCHRONIZED PROCESS NO.	PROCESS NAME	T.I.ME		NUMBER OF CHARACTERS	
		FIRST TOOL REST	SECOND TOOL REST	FIRST TOOL REST	SECOND TOOL REST
01	DRILLING	39 (0'30, 0'09)		13	
02	OUTER DIAME- TER ROUGHING		25(0'18, 0'07)		10
03	OUTER DIAME- TER ROUGHING		73 (0'05, 0'18)		25
03	INNER DIAME- TER ROUGHING	88 (1'10, 0'18)		30	
04	OUTER DIAME- TER FINISHING		48 (0'32, 0'16)		17
04	INNER DIAME- TER FINISHING	31 (0'21, 0'10)		10	
05	THREAD CUTTING	32 (0'25, 0'07)		11	
TOTAL		232 (2'55 , 0'57)			

Fig. 8

☆☆☆NC DATA CREATION ☆   MACHINING TIME

	O1	O2	O3	O4	O5
TOOL REST 1	▨		▨▨▨▨▨	▨▨	▨
TOOL REST 2		▨	▨▨		
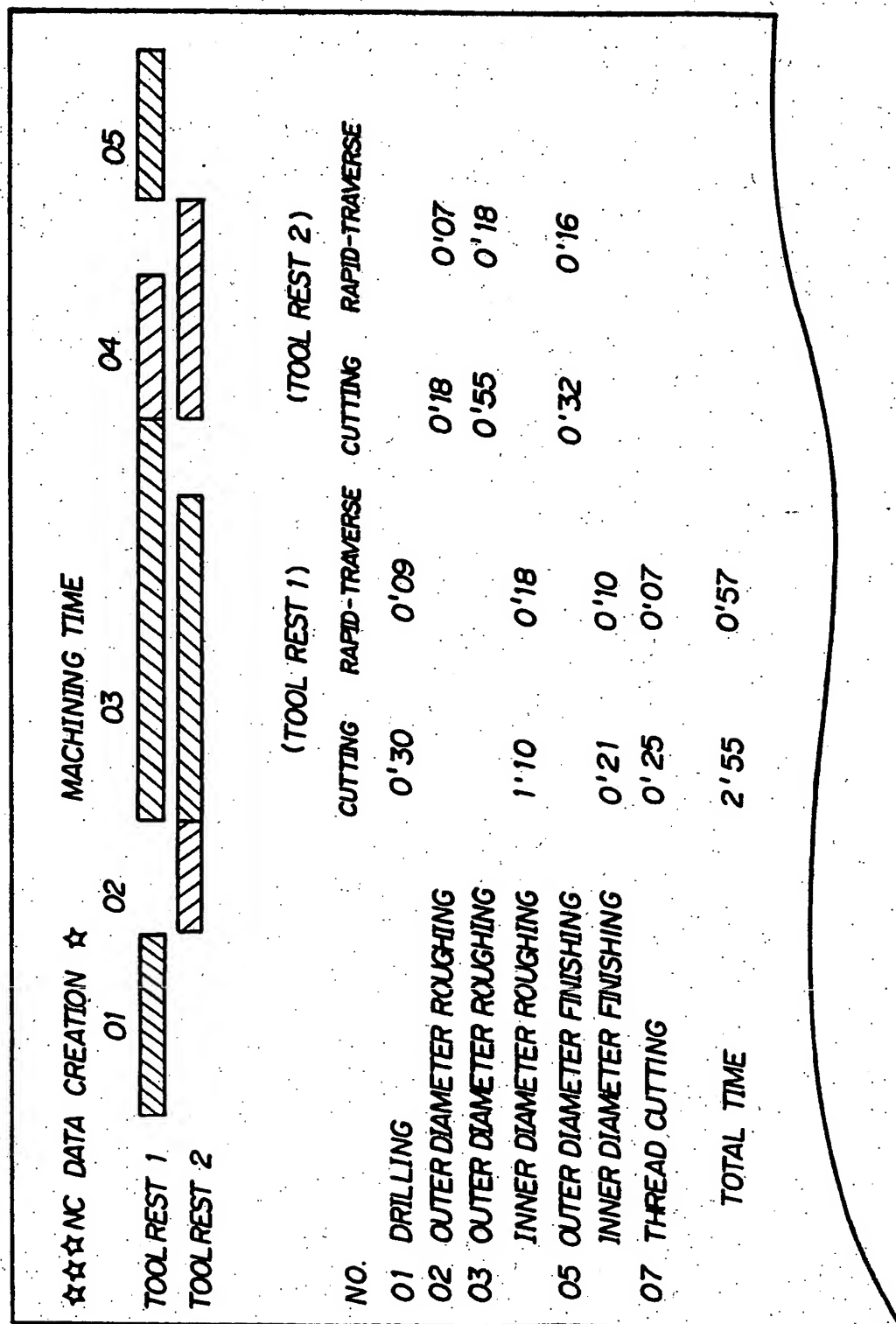
NO.		(TOOL REST 1)		(TOOL REST 2)	
	CUTTING	RAPID-TRAVERSE	CUTTING	RAPID-TRAVERSE	
O1 DRILLING	0'30	0'09			
O2 OUTER DIAMETER ROUGHING			0'18	0'07	
O3 OUTER DIAMETER ROUGHING			0'55	0'18	
INNER DIAMETER ROUGHING	1'10	0'18			
O5 OUTER DIAMETER FINISHING			0'32	0'16	
INNER DIAMETER FINISHING	0'21	0'10			
O7 THREAD CUTTING	0'25	0'07			
TOTAL TIME	2'55	0'57			

International Application No. **PCT/JP87/00100**

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl⁴   B23Q17/00, G05B19/405, G06F15/72

II. FIELDS SEARCHED

Minimum Documentation Searched	
Classification System	Classification Symbols
IPC	B23Q15/00, B23Q17/00, G05B19/405 G06F15/72

Documentation Searched other than Minimum Documentation
to the Extent that such Documents are Included in the Fields Searched

Jitsuyo Shinan Koho	1965 - 1986
Kokai Jitsuyo Shinan Koho	1971 - 1986

III. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
X	JP, A, 58-171241 (Yamazaki Tekkosho Kabushiki Kaisha) 7 October 1983 (07. 10. 83) & FR, A, 2,524,663 & DE, A, 3,311,246 & GB, A, 2,118,328	1-4

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
April 25, 1987 (25. 04. 87)	May 11, 1987 (11. 05. 87)
International Searching Authority	Signature of Authorized Officer
Japanese Patent Office	